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# The price premium for green-labelled housing: Evidence from China

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**Abstract**

The Chinese central government introduced the 'Chinese Green Building Label' in 2008, which makes China one of the few developing countries with an official rating system of buildings' performance in sustainability. This paper investigates the existence and magnitude of the price premium associated with this official green label in the residential sector. Based on a unique data set of green-labelled, newly built housing projects and their non-labelled counterparts from around the country in 2013, an empirical analysis suggests that the labelled housing projects attract a price premium of 6.9% compared with their non-labelled counterparts. Further analysis suggests that this official green label is more effective as a reliable signal of buildings' energy efficiency in the Chinese context compared with developers' self-advertised 'greenness'. These results provide preliminary evidence that with this official rating system, the investment in buildings' energy-efficiency could be potentially profitable for housing developers in China, and such profitability may herald a rapid development of the green housing market in urban China.

**Keywords**

Chinese Green Building Label, green housing, hedonic model, price premium

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## Introduction

The construction and operation of buildings consumes massive amounts of raw materials and energy, and accounts for about one-third of worldwide greenhouse gas emissions

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(Deng et al., 2012). Accordingly, a growing number of major economies have been encouraging the development of energy-efficient and sustainable buildings, or so-called 'green' buildings, as a key aspect of sustainable development. Such efforts are especially important in emerging economies such as China. Currently, China contributes approximately half of the annual floor area of new construction in the world, as well as about 16% of the global building energy consumption (Jennings et al., 2011). These figures are expected to keep increasing because of the continuous urbanisation and economic growth of China.

It is widely recognised that the financial viability of energy-efficiency investment for building owners or developers is essential in promoting the development of green buildings. Many studies conducted in developed economies concluded that compared with their otherwise comparable, non-labelled counterparts, officially green-labelled properties command a significant rent or sale price premium in both the commercial property market (Chegut et al., 2014; Eichholtz et al., 2010; Fuerst and McAllister, 2011; Kok and Jennen, 2012) and the residential housing market (Brounen and Kok, 2011; Deng and Wu, 2014; Deng et al., 2012; Fuerst et al., 2015; Kahn and Kok, 2014). If this premium is large enough to offset the incremental costs of adopting green practice, more owners and developers would be encouraged to invest in green buildings, even without subsidies or mandates from the governments. Kok et al. (2011) believe such a market mechanism is important for explaining the recent rapid growth of green buildings in several major economies.

As we will explain in the next section, a green certification can be a reliable signal for market participants to distinguish between green and non-green buildings, and plays a crucial role in ensuring the financial sustainability of greening efforts. However, although the Chinese government has been encouraging the development of energy-efficient buildings since the 1980s, no green rating system existed until very recently in China. This lack of information is believed to have substantially hindered the development of green buildings (Zheng et al., 2012). The situation started to improve when a nationwide official rating system, the 'Chinese Green Building Label' (hereafter CGBL), was introduced in 2008. The CGBL has been accepted by an increasing number of market participants, providing an opportunity to estimate the green price premium and thus the financial viability of green buildings in current China (Ye et al., 2013; Zhang and Liu, 2013).

This paper provides a comprehensive investigation on the price premium associated with the CGBL for new residential units, based on a unique data set including 163 CGBL-labelled projects around mainland China and their comparable non-labelled counterparts. The results are generally encouraging. Controlling for other factors, the transaction price of a housing unit in a labelled project is 6.9% higher than if it were in a non-labelled project. Referring to the incremental costs of CGBL-labelled housing projects, the results suggest that the price premium can be expected to ensure the financial viability of energy-efficiency investments and thus attract more developers to devote to such green efforts. We also shed more light on the role of the CGBL as a reliable signal of building energy efficiency. The results suggest that when information from the CGBL is available, developers can no longer obtain a premium simply by self-advertising the 'greenness' of their developments as revealed in Zheng et al. (2012). Meanwhile, we found no significant price premium of the LEED label either, which is popular in several developed economies but pointed out by some previous research to be unsuitable for the Chinese context.

## 'Chinese Green Building Label' rating system

Several studies have emphasised the importance of green rating systems in promoting green buildings. Buildings are a typical experience good (Nelson, 1970) – their qualities, such as energy efficiency, are only revealed gradually upon consumption. The problems of information asymmetry and adverse selection are especially serious in the green building sector: most users do not have the specialised knowledge or sufficient information to determine the energy efficiency of buildings, and such 'energy literacy' is particularly low in the residential sector (Brounen et al., 2013; Heinzle et al., 2013). These problems indicate that there is a need for reliable market signals, such as green building certifications provided by third parties such as governments or independent institutions, which have been proved as a relatively low-cost strategy to overcome the information problems (Heinzle et al., 2013; Kahn and Kok, 2014). The demand for such signals has led to a proliferation of green labels in major economies, such as LEED and Energy Star in the USA, BREEAM in the UK, CASBEE in Japan, and Green Mark in Singapore.

However, while the importance of developing energy-efficient buildings has been widely recognised in mainland China, there was no official rating system for green buildings until very recently. This absence led to two problems. First, developers or owners of energy-efficient buildings in China had to seek certifications from other global rating systems, such as LEED.[1] However, these systems, which originated in developed economies, may not fit China's context well. For example, according to Zhu and Lin (2012), the average energy consumption per square metre of floor area in US buildings is about three times as much as that in China. This implies that even if a LEED-labelled building consumes 60% less energy than its non-labelled counterparts in the USA, it may still not necessarily be 'greener' than conventional buildings in China.[2] Second, the absence of an official system created opportunities for fake- or over-advertising in the market. For example, Zheng et al. (2012) investigated energy-efficiency related advertisements by developers in Beijing between 2003 and 2008, and found that a substantial portion of the self-advertised 'green' residential buildings over-advertised their 'greenness'.

The situation has started to change recently. To facilitate the development of green buildings, the Ministry of Housing and Urban-Rural Development (MOHURD) adapted the standards of LEED and CASBEE to China's conditions and issued the *Evaluation Standards for Green Building* in 2006 (Zhu and Lin, 2012). Based on that, a nationwide programme, the 'Chinese Green Building Label' (CGBL), was launched in 2008, providing the first official system for evaluating and rating buildings' performance in sustainability in mainland China. The *Evaluation Standards for Green Buildings* covers six categories, namely, land use and outdoor environment, energy saving, water saving, material saving, indoor environmental quality and operational management. In each category, the detailed requirements are summarised as a list including prerequisite items, optional items and optimal items. A building seeking to be CGBL-labelled has to meet all the prerequisite items first, and then its rating level (one-star, two-star or three-star) is determined based on how well it meets the optional and optimal items. The owner or developer of a building can apply for certification at the design stage (i.e. the design certification) based on the inspection of design documents, or/and the operation stage (i.e. the operation certification) based on the post-occupancy evaluation after the building being in operation for at least one year.[3]

To further encourage developers to apply for the CGBL, an incentive scheme was introduced in 2012. According to the scheme, the developer of a new building with a two-star rating would receive a subsidy of 45 yuan/m$^2$ of floor area from the central government, and the corresponding subsidy for three-star rated buildings would be 80 yuan/m$^2$.[4] However, according to most existing surveys on incremental costs for CGBL-labelled buildings (which will be reviewed in detail later), it is very likely that such a government subsidy alone is not sufficient to encourage developers' green practice. In other words, the financial feasibility of developing green buildings still relies on the existence and magnitude of a green price premium in the housing market, which is the focus of the following empirical analysis.

## Data

To test the existence and magnitude of the price premium associated with the CGBL, we use a data set of CGBL-labelled housing projects and their comparable non-labelled counterparts from around China. Instead of resale or rental transactions, we focus on the newly built housing market since it provides the only opportunity for housing developers to receive a return to their energy-efficient investments (Deng and Wu, 2014).

According to MOHURD, 429 housing projects had been CGBL-labelled in mainland China by April 2013. We exclude all the public housing since their transaction prices do not necessarily reflect their market prices, and all landed projects (e.g. villas) because the hedonic attributes available may be insufficient to explain their prices. With the help of Soufun, a leading real estate data vendor in China, we focus on the private housing projects that were listed in the newly built housing market in May 2013. These procedures lead to a sample of 167 CGBL-labelled projects. For each of these projects, following the strategy of Eichholtz et al. (2010), we search Soufun's database for newly built private housing projects within a radius of 1500 m,[5] which were also on the market in May 2013, as the control group. A total of 585 non-labelled housing projects are matched to 163 of these 167 labelled projects following such procedures; four labelled projects could not be matched with any non-labelled projects and are thus excluded from the analysis. Therefore, our data set includes 748 housing projects. The 163 labelled projects include 42 three-star, 68 two-star, and 53 one-star projects. 157 projects were certified at the design stage, compared with only six at the operation stage.[6] As depicted in Figure 1, these labelled projects are distributed across 59 cities in 25 provinces.

We then use Soufun to obtain the average transaction price in May 2013 (*HP*) for each sample project. This is calculated by dividing the total value of new housing units sold in the project in the month by the total floor area of these units. The unconditional average price is 12,320 yuan/m$^2$ for the labelled projects, and 10,250 yuan/m$^2$ for the non-labelled projects. This provides preliminary evidence for the existence of a green price premium, although we leave more definitive conclusions until later.

Besides the key dummy variable of *CGBL*, we also test two other potential signals. First, as mentioned previously, before CGBL, LEED was the most popular green building certification in mainland China. Out of the 56 LEED-registered and certified residential projects by April 2013, 15 projects were on the new housing market in May 2013. We collect information on these 15 LEED-labelled projects,[7] as well as 36 non-labelled projects that match these LEED-labelled projects following the same procedures as mentioned before. This sample is used to examine the existence of a price premium associated with the LEED label

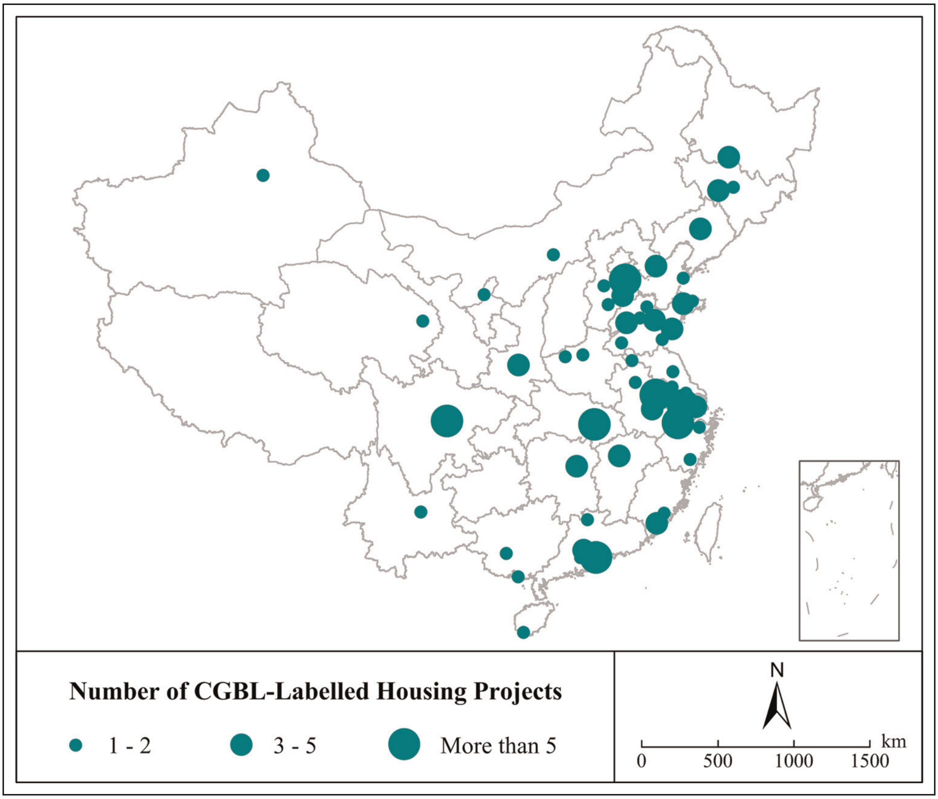


**Figure 1.** Distribution of CGBL-labelled housing projects in the sample.
*Source*: Authors' calculations based on data from MOHURD and Soufun.

(*LEED*). Second, we collect information on the 'marketed greenness' based on developers' self-advertisements. We obtain information from fang.com, the largest and most influential advertising platform for newly built housing in mainland China. For each project, developers choose some features as the most attractive characteristics and highlight these tags on the website, such as 'in a good school district', 'along the subway' and 'livable and eco-friendly'. We classify the group of self-advertised 'green' projects with those marked as 'livable and eco-friendly'. A total of 32% of the CGBL-labelled projects highlighted 'livable and eco-friendly' as a key feature, while about 18% of the non-labelled projects also selected this tag. We test whether such 'marketed greenness' (*AD*) affects transaction prices, especially when the projects are not CGBL-labelled.

We also obtain major hedonic attributes not related to energy efficiency for both the labelled and non-labelled projects from Soufun. We first collect the information about typical features in distinguishing a luxury residential project from an ordinary one: the floor area ratio (*FAR*), building type (*SLAB, TOWER, COMBINED*), the ratio between green space area and total land area (*GREENRATE*), whether the units were decorated on delivery (*DECORATION*), and property management fee (*PFEE*). In current China, a luxury project is more likely to be in slab-type buildings, with lower floor area ratio and higher green rate, decorated upon delivery, and with a higher property management level (and thus higher property management fee). The second group of variables is locational attributes. Although a CGBL-labelled project and its matched non-labelled projects are within a radius of 1500 m and thus can be considered to be similar in many locational characteristics, there still may be some difference in their distances to the amenities available within their locality. Therefore, we further control for the distances to the nearest park/river/lake/sea (*D_VIEW*), bus station (*D_BUS*), elementary or middle school (*D_SCHOOL*), hospital (*D_HOSPITAL*), department store (*D_MARKET*), respectively, and whether a subway station was located within a radius of 1 km (*SUBWAY*).[8] We also introduce several developer attributes, including whether the project was developed by a well-known developer (*FAME*),[9] and whether the developer is listed on exchanges in mainland China, Hong Kong or abroad (*LISTED_CHINA, LISTED_HK, LISTED_ABROAD*). In addition, we include the time-on-market of the sample projects (i.e. the number of years that the project has been on the market by 2013; *LISTYEAR*), to control for the potential effect of developers' pricing strategies at different marketing stages of a project. Finally, we obtain the incremental costs associated with the CGBL as compared with conventional code-complaint buildings (*GREEN_COST*) from the MOHURD, but only 23 of the 163 CGBL-labelled projects are available in terms of this information. The definitions and summary statistics of the variables are listed in Table 1.

## Empirical analysis

### Existence and magnitude of the green price premium

Most existing studies examined the green price premium by directly relating the projects' transaction prices to the CGBL and a set of physical, locational and amenity control variables via a hedonic model (Chegut et al., 2014; Deng and Wu, 2014; Fuerst et al., 2015; Zhang and Liu, 2013). A major challenge here is the potential effect of omitted variables. Besides controlling for the hedonic variables introduced above, we choose to take advantage of the inherent homogeneity between projects in each of the 151 groups.[10] Typically one group consists of one labelled project and several matched non-labelled projects, which can be considered to share at least some (unobserved) characteristics, especially in the locational perspective and housing market conditions (Eichholtz et al., 2010). In addition, the 151 groups are distributed in 59 cities, among which the housing market conditions vary greatly. To capture such multiple and nested geographies – housing projects in the sample are nested in groups, and groups are nested in cities, we adopt the multilevel model (Leishman et al., 2013; Orford, 2000). Specifically, the three-level model contains a set of random effects to control for city-specific variation, a second set of random effects to control for group-specific variation, and a random-error term to control for projects' variation. Three hierarchical levels (project-level, group-level, and city-level) of housing price variations are incorporated into the traditional hedonic specification by expanding the error term; that is:

$$\ln(\boldsymbol{HP}) = \alpha + \beta \cdot \boldsymbol{CGBL} + \boldsymbol{\gamma} \cdot \boldsymbol{X} + \boldsymbol{\mu}_{group} + \boldsymbol{\mu}_{city} + \boldsymbol{\varepsilon} \quad (1)$$

where: $\boldsymbol{HP}$ is the average price of each project; $\boldsymbol{\alpha}$ is the constant; $\boldsymbol{CGBL}$ is a vector of dummy variables indicating the CGBL-labelled projects; $\boldsymbol{X}$ is the non-energy efficiency hedonic attributes; $\boldsymbol{\mu}_{group}$ and $\boldsymbol{\mu}_{city}$ are group-level (level-2) and city-level (level-3) random intercepts, respectively; and $\boldsymbol{\varepsilon}$ is the overall (level-1) error term. The random intercepts and error terms are assumed to be mutually independent. By expanding the

**Table 1.** Definition and summary statistics of key variables.

| Variables | Definition | Obs. | Mean | SD | Min. | Max. |
|---|---|---|---|---|---|---|
| *HP* | Average presale price in May 2013 (10,000 yuan/m$^2$) | 797 | 1.190 | 0.876 | 0.325 | 8.200 |
| *CGBL* | Whether the project was CGBL-labelled (1 = yes, 0 = o/w) | 797 | 0.205 | 0.404 | 0.000 | 1.000 |
| *THREE_STAR* | Whether the project was three-star rated (1 = yes, 0 = o/w) | 797 | 0.053 | 0.224 | 0.000 | 1.000 |
| *TWO_STAR* | Whether the project was two-star rated (1 = yes, 0 = o/w) | 797 | 0.085 | 0.280 | 0.000 | 1.000 |
| *ONE_STAR* | Whether the project was one-star rated (1 = yes, 0 = o/w) | 797 | 0.067 | 0.249 | 0.000 | 1.000 |
| *DESIGN* | Whether the project was certified at the design stage (1 = yes, 0 = o/w) | 797 | 0.197 | 0.398 | 0.000 | 1.000 |
| *OPERATION* | Whether the project was certified at the operation stage (1 = yes, 0 = o/w) | 797 | 0.008 | 0.087 | 0.000 | 1.000 |
| *LEED* | Whether the project was LEED-labelled (1 = yes, 0 = o/w) | 797 | 0.019 | 0.136 | 0.000 | 1.000 |
| *AD* | Whether the project was self-advertised as ‘livable and eco-friendly’ on fang.com (1 = yes, 0 = o/w) | 797 | 0.210 | 0.407 | 0.000 | 1.000 |
| *FAR* | Floor area ratio | 797 | 2.835 | 1.537 | 0.300 | 14.41 |
| *GREENRATE* | Ratio between green space area and total land area | 797 | 0.368 | 0.086 | 0.030 | 0.720 |
| *DECORATION* | Whether the units were decorated on delivery (1 = yes, 0 = o/w) | 797 | 0.227 | 0.419 | 0.000 | 1.000 |
| *PFEE* | Property management fee per month (yuan/m$^2$) | 797 | 2.056 | 1.147 | 0.010 | 8.900 |
| *SLAB* | Whether the project consists of slab-type buildings | 797 | 0.533 | 0.499 | 0.000 | 1.000 |
| *TOWER* | Whether the project consists of tower-type buildings | 797 | 0.198 | 0.399 | 0.000 | 1.000 |
| *COMBINED* | Whether the project consists of slab-tower-combined buildings | 797 | 0.269 | 0.443 | 0.000 | 1.000 |
| *PARK* | Average number of parking spaces per housing unit in the project | 685 | 0.980 | 0.644 | 0.000 | 6.020 |
| *FAME* | Whether the project was developed by a well-known developer (1 = yes, 0 = o/w) | 797 | 0.212 | 0.409 | 0.000 | 1.000 |
| *LISTED_CHINA* | Whether the developer is listed on exchanges in mainland China | 797 | 0.138 | 0.345 | 0.000 | 1.000 |
| *LISTED_HK* | Whether the developer is listed on the Hong Kong Exchange | 797 | 0.120 | 0.326 | 0.000 | 1.000 |
| *LISTED_ABROAD* | Whether the developer is listed on other exchanges abroad | 797 | 0.004 | 0.061 | 0.000 | 1.000 |
| *LISTYEAR* | Number of years that the project has been on the market by 2013 | 797 | 1.054 | 0.912 | 0.000 | 2.000 |
| *D_VIEW* | Distance to the nearest park, river, lake or sea (km) | 797 | 1.082 | 0.778 | 0.010 | 5.540 |
| *D_BUS* | Distance to the nearest bus station (km) | 797 | 0.268 | 0.272 | 0.010 | 3.220 |
| *D_SCHOOL* | Distance to the nearest elementary or middle school (km) | 797 | 0.783 | 0.858 | 0.020 | 7.129 |
| *D_HOSPITAL* | Distance to the nearest hospital (km) | 797 | 0.736 | 0.681 | 0.020 | 5.493 |
| *D_MARKET* | Distance to the nearest department store (km) | 797 | 1.084 | 1.303 | 0.005 | 18.16 |
| *SUBWAY* | Whether there is a subway station within 1 km (1 = yes, 0 = o/w) | 797 | 0.171 | 0.376 | 0.000 | 1.000 |
| *GREEN_COST* | Incremental costs of green design and technologies (10000 yuan/m$^2$) | 23 | 0.013 | 0.012 | 0.001 | 0.040 |

error term to several higher levels, multilevel model can address the heteroscedasticity and spatial autocorrelation problems caused by submarkets and can capture the hierarchical structure of the housing market.

The results are provided in column (1) of Table 2, with the natural logarithm term of the housing price as the dependent variable[11] estimated based on the maximum likelihood method. Our major interest, the dummy variable of *CGBL*, is statistically significant and positive in the model. According to the coefficient, controlling for other factors, the price of a housing unit in a newly built CGBL-labelled housing project is 6.9% ($\exp(0.0666) \approx 1.0689$) higher than its non-labelled counterparts. The coefficients for the control variables are generally consistent with expectations.

More details on the green price premium are investigated in the following two columns. We first replace the *CGBL* dummy with three dummy variables indicating the rating levels. The coefficients of *ONE_STAR* and *TWO_STAR* are significantly positive in the model, as reported in column (2). In general, the green price premium increases with the rating level: relative to a unit in a comparable but non-labelled newly built housing project, the transaction price of a unit in a one-star rated project is 5.8% higher, with the premium reaching 8.7% for a two-star rated project. Interestingly, the price premium for a three-star rated project is lower at 4.3% and is only marginally significant. This pattern is not unique to our analysis, and has been found in several previous studies (Deng et al., 2012; Kahn and Kok, 2014; Kok and Jennen, 2012). The small number of top-rated housing projects in the sample may be one possible reason for this phenomenon.

In column (3), we use two dummy variables to denote the rating stages. While both variables are positive and statistically significant, the coefficient of *OPERATION* is substantially larger than that of *DESIGN*, although only 6 of the 163 labelled projects were certified during the operation stage. The transaction price of a housing project with operation certification can be 17.4% higher than its counterparts, while a project with design certification only commands a premium of 6.3%. These results are consistent with the findings of Deng and Wu (2014): compared with 'expectations' based on design documents, households are willing to pay more when they can directly observe the energy efficiency with utility bills available at the operation stage. In addition, studies conducted by engineers suggest that without professional facility management, green buildings can hardly save energy as expectations (Sabapathy et al., 2010). The operation certification based on post-occupancy evaluation indicates good facility management and actual energy efficiency, and thus leads to a higher price premium.

## Robustness checks

In this subsection, we test the robustness of the green price premium. We start with the potential effect of the empirical strategy. Besides the basic specification using the three-level model, in Panel A of Table 3 we test several alternative methods. In column (1), we replace the three-level model with a two-level model; that is, we only specify a random effect at the group level, without any consideration of potential city-level nesting. In column (2), following the method adopted by Eichholtz et al. (2010), we use the conventional OLS regression and control for the group fixed effects, with standard errors clustered at the group level. Then, we adopt the spatial autoregressive specification (Can, 1992) in column (3), instead of the group-level random or fixed effects, to explicitly address the functional interdependence among housing prices of adjacent projects, as shown in equations (2) and (3):

**Table 2.** Existence and magnitude of the green price premium.

| Dependent variable | (1) *ln(HP)* | (2) *ln(HP)* | (3) *ln(HP)* |
|---|---|---|---|
| *CGBL* | 0.0666*** | | |
| | (5.14) | | |
| *THREE_STAR* | | 0.0425 | |
| | | (1.62) | |
| *TWO_STAR* | | 0.0834*** | |
| | | (4.05) | |
| *ONE_STAR* | | 0.0562*** | |
| | | (3.48) | |
| *DESIGN* | | | 0.0608*** |
| | | | (4.49) |
| *OPERATION* | | | 0.160*** |
| | | | (8.94) |
| *FAR* | −0.0146** | −0.0143** | −0.0142** |
| | (−2.22) | (−2.15) | (−2.14) |
| *GREENRATE* | 0.0232 | 0.0273 | 0.0247 |
| | (0.38) | (0.45) | (0.41) |
| *DECORATION* | 0.161*** | 0.164*** | 0.162*** |
| | (8.29) | (8.01) | (8.27) |
| *ln(PFEE)* | 0.0968*** | 0.0963*** | 0.0976*** |
| | (2.81) | (2.78) | (2.82) |
| *SLAB* | −0.0178 | −0.0185 | −0.0178 |
| | (−1.08) | (−1.10) | (−1.07) |
| *TOWER* | −0.0288 | −0.0300* | −0.0295 |
| | (−1.59) | (−1.65) | (−1.61) |
| *FAME* | 0.00776 | 0.0122 | 0.0102 |
| | (0.32) | (0.51) | (0.42) |
| *LISTED_CHINA* | −0.0165 | −0.0167 | −0.0154 |
| | (−0.94) | (−0.95) | (−0.87) |
| *LISTED_HK* | 0.0270 | 0.0264 | 0.0278 |
| | (1.22) | (1.18) | (1.26) |
| *LISTED_ABROAD* | 0.169 | 0.173 | 0.174 |
| | (1.22) | (1.24) | (1.26) |
| *LISTYEAR* | 0.0145 | 0.0149 | 0.0150 |
| | (1.55) | (1.60) | (1.62) |
| *ln(D_VIEW)* | −0.0534*** | −0.0528*** | −0.0538*** |
| | (−4.45) | (−4.40) | (−4.49) |
| *ln(D_BUS)* | −0.0111* | −0.0112* | −0.0120* |
| | (−1.67) | (−1.67) | (−1.78) |
| *ln(D_SCHOOL)* | −0.00962 | −0.00899 | −0.00898 |
| | (−1.09) | (−1.02) | (−1.02) |
| *ln(D_HOSPITAL)* | −0.0127 | −0.0124 | −0.0121 |
| | (−1.51) | (−1.49) | (−1.44) |
| *ln(D_MARKET)* | −0.00200 | −0.00231 | −0.00167 |
| | (−0.30) | (−0.34) | (−0.25) |
| *SUBWAY* | 0.0976*** | 0.0953*** | 0.0974*** |
| | (4.02) | (3.97) | (4.05) |
| Constant | −0.236*** | −0.238*** | −0.240*** |
| | (−3.81) | (−3.85) | (−3.86) |
| $ln\sigma_{u_{group}}$ | −1.349*** | −1.349*** | −1.351*** |
| | (−14.41) | (−14.34) | (−14.39) |
| $ln\sigma_{u_{city}}$ | −1.103*** | −1.102*** | −1.104*** |

*(continued)*

**Table 2.** Continued

| Dependent variable | (1) *ln(HP)* | (2) *ln(HP)* | (3) *ln(HP)* |
|---|---|---|---|
| | (−8.07) | (−8.06) | (−8.09) |
| $ln\sigma_e$ | −2.089*** | −2.091*** | −2.091*** |
| | (−44.76) | (−44.11) | (−44.50) |
| *N* | 748 | 748 | 748 |
| −2(log-likelihood) | −458.0 | −460.2 | −460.6 |

*Notes*: Robust *t*-statistics are presented in parentheses. Significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

$$\ln(\boldsymbol{HP}) = \lambda \boldsymbol{W} \cdot \ln(\boldsymbol{HP}) + \alpha + \beta \cdot \boldsymbol{CGBL} + \boldsymbol{\gamma} \cdot \boldsymbol{X} + \boldsymbol{u} \quad (2)$$

$$\boldsymbol{u} = \rho \boldsymbol{Wu} + \boldsymbol{\varepsilon} \quad (3)$$

where: $\boldsymbol{W}$ is the spatial weighting matrix that parameterises the distances between neighbourhoods; $w_{ij} = 1/d_{ij}$ if projects $i$ and $j$ are in the same city, with $d_{ij}$ as the distance between projects $i$ and $j$ (in km), and $w_{ij} = 0$ for projects in different cities; $\boldsymbol{u}$ represents spatially correlated residuals and $\boldsymbol{\varepsilon}$ represents the i.i.d. error terms. We use a heteroscedastic robust form of the generalised spatial two-stage least square estimation (Arraiz et al., 2010). In column (4), instead of a cross-sectional model, we collect the annual average transaction price of each project since it was put on market during 2011–2014, and thus establish a panel data model with year fixed effects. The results are generally consistent across all of these alternative specifications: the coefficient of *CGBL* is always significantly positive, and the green price premium ranges between 5.9% (column (4)) and 7.0% (column (2)). Therefore, it is reasonable to expect that the green price premium revealed is not sensitive to empirical model settings.[12]

The empirical findings are also consistent across several robustness checks regarding potential omitted variables (Panel B of Table 3). First, in current China, the availability of parking space is an important feature indicating luxury housing projects, though such information is only available for part of the sample projects. Therefore, besides the hedonic variables in Table 2, we further introduce the average number of parking spaces per housing unit (*PARK*) in column (1). The coefficient of *PARK* is significant, and the green price premium only changes slightly. The second concern originates from the potential omitted variables associated with developers: a few leading developers dominate the supply of green housing, which may also command a premium for their reputation and thus lead to an overestimation of the green price premium. Although we have already included variables indicating well-known and listed developers in the basic specification, in column (2) we further control the fixed effects for developers who have developed more than two projects in the sample, and the result remains robust. In column (3), we also try excluding all projects developed by any specific leading developer, such as Vanke, and the result remains consistent. Finally, we employ the Propensity Score Matching (PSM) procedures to match each CGBL-labelled project with the most similar project in its comparable but non-labelled group according to their propensity scores, which reflect the probability that their non-energy efficiency-related hedonic attributes are identical to the CGBL-labelled project (Deng et al., 2012; Deng and Wu, 2014). While the sample of the control group reduces to 163 non-labelled projects, the findings in column (4) do not change qualitatively.

We further test whether the green price premium is robust across different cities in Panel C of Table 3. First, some previous studies have revealed that the price premium of green buildings is negatively correlated with the number of green buildings on the market (Chegut et al., 2014; Kahn and Kok, 2014). In some nascent green housing markets, such as cities with very few green housing projects, market participants may not have sufficient experience and information, and therefore may misprice these green projects. To exclude such effects, in column (1), we only include projects in cities with at least three CGBL-labelled housing projects. The magnitude of the green price premium is slightly smaller, but is still statistically significant. Second, China is well-known for its vast geographical scale and great climatic diversity, and the energy consumption might vary substantially among cities. In particular, energy consumption in cities where winter heating is necessary (located in the north to the line tracing the Qin Mountains and Huai River) should be higher than that in southern cities. In order to test whether the green price premium exists in all cities, instead of just the northern cities, we include a dummy *NORTH* indicating whether the building is located in a city requiring winter heating in column (2). The green price premium remains robust and does not differ significantly between cities with different building energy intensities.[13] Third, we examine whether the green price premium only exists in big cities by employing a dummy *BIGCITY* to indicate the 35 big cities defined by National Bureau of Statistics. The green price premium still remains robust and is not related to the city size.

### Benefit-cost analysis from developers' perspective

The next, and perhaps more important question is, whether the price premium is sufficiently high to offset the incremental (upfront) costs that developers have to undertake to earn the CGBL certification and thus make developers' green investments financially feasible (Deng and Wu, 2014).

We adopt two strategies to investigate this issue. First, we directly test how the incremental costs affect the magnitude of green premium. As introduced before, with the help of MOHURD, we are able to collect the information on developers' self-reported incremental costs associated with green design and technologies in 23 of the 163 CGBL-labelled projects, and in Panel A of Table 4 we focus on these 23 projects and their comparable non-labelled counterparts. In column (1), we re-estimate the price premium of CGBL using this subsample. Although this sample is relatively small, the coefficient of *CGBL* is still significant at the 10% level. In column (2), we replace *CGBL* with *GREEN_COST*, the magnitude of incremental costs of green design and technologies,[14] and the coefficient turns out to be at most marginally significant. We further include both *CGBL* and the interaction term of *CGBL* and *GREEN_COST* in column (3). While the CGBL-labelled projects enjoy a significant price premium, the price premium does not increase with the incremental costs, implying that the price premium is associated with the CGBL certification, instead of the incremental costs.

Such findings are not surprising. Several studies in the engineering field have reported that significant improvements in energy efficiency and indoor environment do not necessarily cost more (Bartlett and Howard, 2000; Häkkinen and Belloni,

**Table 3.** Robustness checks.

| **(A) *Alternative methods*** | Two-level model | OLS with group fixed effects | Spatial autoregressive model | Panel three-level model |
|---|---|---|---|---|
| Dependent variable | (1) *ln(HP)* | (2) *ln(HP)* | (3) *ln(HP)* | (4) *ln(HP)* |
| *CGBL* | 0.0651*** | 0.0679*** | 0.0639*** | 0.0570*** |
| | (4.70) | (4.35) | (3.08) | (3.95) |
| Control variables | Yes | Yes | Yes | Yes |
| Group fixed effects | No | Yes | No | No |
| Year fixed effects | No | No | No | Yes |
| Group-level random effects | Yes | No | No | Yes |
| City-level random effects | No | No | No | Yes |
| $\lambda$ | | | 0.0575*** | |
| | | | (6.42) | |
| $\rho$ | | | 0.0728*** | |
| | | | (5.93) | |
| *N* | 748 | 748 | 748 | 1983 |
| −2(log-likelihood) | −404.6 | | | −1370.6 |
| $R^2$ | | 0.953 | | |

| **(B) *Potential omitted variables*** | Parking spaces | Developer fixed effects | Excluding Vanke | Propensity Score Matching |
|---|---|---|---|---|
| Dependent variable | (1) *ln(HP)* | (2) *ln(HP)* | (3) *ln(HP)* | (4) *ln(HP)* |
| *CGBL* | 0.0623*** | 0.0589*** | 0.0713*** | 0.0555*** |
| | (4.25) | (4.15) | (5.57) | (2.94) |
| *PARK* | 0.0346*** | | | |
| | (2.61) | | | |
| Control variables | Yes | Yes | Yes | Yes |
| Developer fixed effects | No | Yes | No | No |
| Group-level random effects | Yes | Yes | Yes | Yes |
| City-level random effects | Yes | Yes | Yes | Yes |
| *N* | 641 | 748 | 715 | 326 |
| −2(log-likelihood) | −332.6 | −476.6 | −437.8 | −40.76 |

| (C) Inter-city diversity | Cities with multiple labelled projects | North and south | Big cities |
|---|---|---|---|
| Dependent variable | (1) *ln(HP)* | (2) *ln(HP)* | (3) *ln(HP)* |
| *CGBL* | 0.0623*** | 0.0608*** | 0.0646*** |
| | (3.79) | (3.71) | (4.37) |
| *CGBL*NORTH* | | 0.0135 | |
| | | (0.55) | |
| *NORTH* | | −0.282*** | |
| | | (−2.89) | |
| *CGBL*BIGCITY* | | | 0.00348 |
| | | | (0.17) |
| *BIGCITY* | | | 0.341*** |
| | | | (3.63) |
| Control variables | Yes | Yes | Yes |
| Group-level random effects | Yes | Yes | Yes |
| City-level random effects | Yes | Yes | Yes |
| *N* | 558 | 748 | 748 |
| −2(log-likelihood) | −357.2 | −466.2 | −470.6 |

*Notes*: (1) The control variables are consistent with Table 2. (2) Robust *t*-statistics are presented in parentheses. Significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

2011; Zhang et al., 2011; Zhu et al., 2010). More specifically, there are two strategies in designing green buildings – passive design and active design. Passive design focuses on building envelope to optimise the gain and loss of solar energy and thus reduce energy consumption, while active design relies on mechanical equipment for heating or cooling (Zhang et al., 2011). Passive designs, such as better-insulated windows and walls, green roofs and external shading, are comparatively inexpensive compared with active designs such as solar photovoltaic and heat pump systems (Zhang et al., 2011; Zhu et al., 2010). Therefore, developers could wisely choose passive design methods to achieve the standards of CGBL and win the price premium.

As the second step, we compare the magnitudes of green premium and incremental cost. The marginally significant but positive coefficient of *GREEN_COST* in column (2) of Panel A in Table 4 suggests that the average green incremental cost of 130 yuan/m$^2$ in our sample can yield a price premium of 301 yuan/m$^2$.[15] We also review the existing surveys on the incremental costs for the CGBL (Table 5) and then compare with the price premium estimated in this paper. In general, the incremental costs of one-, two- and three-star rated housing are less than 100, 300, and 500 yuan/m$^2$, respectively, with a remarkable declining trend during recent years.[16] Our back-of-the-envelope calculations suggest that in China's newly built housing market, on average it is currently a financially feasible, or even profitable, decision for developers to invest in green buildings. For instance, a two-star rated project will, on average, receive an incremental monetary benefit of about 937 yuan/m$^2$, consisting of 892 yuan/m$^2$ from the price premium[17] and 45 yuan/m$^2$ from the central government subsidy. Such a benefit is considerably higher than most cost estimates for two-star rated projects as listed in Table 5, which range between 35 and 282 yuan/m$^2$. These results imply that even without considering any indirect benefits, such as gains to the wider society, the financial advantages of developing green housing may be enough to motivate developers to continue their efforts in this regard. Such results also serve as a first evidence that the market mechanism can play an important role in promoting green housing development in this emerging economy, just as revealed in other developed economies.

### *Importance of the CGBL as a signal*

As a final step, we further investigate the importance of the CGBL as a reliable signal of buildings' energy efficiency. More specifically, our interest here is that when the CGBL is widely accepted, whether the use of other green labels such as LEED or self-advertised 'greenness' still provide value to developers.

We start by comparing the price premiums between CGBL and LEED. In Panel B of Table 5, we further introduce 15 LEED-labelled projects and 36 matched non-labelled projects, and include the dummy variables of both *CGBL* and *LEED*. While the coefficient of the *CGBL* variable remains almost unchanged, the *LEED* dummy is insignificant in the model. In the second column, we further divide the treatment group into three categories. Although the category with both the CGBL and LEED certifications (*CGBL_LEED*) only includes two projects, it commands the highest price premium, followed by the projects with CGBL only (*CGBL_NOLEED*). The price premium for the projects with LEED only (*NOCGBL_LEED*) is insignificant.

Next, we turn to the self-advertised 'green' projects. In the first column of Panel C in Table 5, we replace *CGBL* with *AD*, which reflects whether the developer advertised the project as energy-efficient on the

**Table 4.** Comparison of price premiums associated with CGBL, incremental costs, and other potential signals.

***(A) Price premiums associated with incremental costs***

| Dependent variable | (1) *ln(HP)* | (2) *ln(HP)* | (3) *ln(HP)* |
|---|---|---|---|
| *CGBL* | 0.0607* | | 0.0572* |
| | (1.86) | | (1.86) |
| *GREEN_COST* | | 2.303 | |
| | | (1.33) | |
| *CGBL*GREEN_COST* | | | 0.260 |
| | | | (0.13) |
| Control variables | Yes | Yes | Yes |
| Group-level random effects | Yes | Yes | Yes |
| City-level random effects | Yes | Yes | Yes |
| *N* | 116 | 116 | 116 |
| −2(log-likelihood) | −101.68 | −100.14 | −101.68 |

***(B) Price premiums associated with LEED***

| Dependent variable | (1) *ln(HP)* | (2) *ln(HP)* |
|---|---|---|
| *CGBL* | 0.0623*** | |
| | (4.95) | |
| *LEED* | 0.0526 | |
| | (1.61) | |
| *CGBL_LEED* | | 0.0830** |
| | | (2.30) |
| *CGBL_NOLEED* | | 0.0628*** |
| | | (4.90) |
| *NOCGBL_LEED* | | 0.0581 |
| | | (1.56) |
| Control variables | Yes | Yes |
| Group-level random effects | Yes | Yes |
| City-level random effects | Yes | Yes |
| *N* | 797 | 797 |
| −2(log-likelihood) | −420.6 | −420.8 |

***(C) Price premiums associated with 'marketed greenness'***

| Dependent variable | (1) *ln(HP)* | (2) *ln(HP)* | (3) *ln(HP)* |
|---|---|---|---|
| *CGBL* | | 0.0641*** | |
| | | (4.98) | |
| *AD* | 0.0274* | 0.0176 | |
| | (1.85) | (1.23) | |
| *CGBL_AD* | | | 0.0775*** |
| | | | (3.36) |
| *CGBL_NOAD* | | | 0.0668*** |
| | | | (4.24) |
| *NOCGBL_AD* | | | 0.0204 |
| | | | (1.29) |
| Control variables | Yes | Yes | Yes |
| Group-level random effects | Yes | Yes | Yes |
| City-level random effects | Yes | Yes | Yes |
| *N* | 748 | 748 | 748 |
| −2(log-likelihood) | −437.0 | −459.4 | −459.6 |

*Notes*: (1) The control variables are consistent with Table 2. (2) Robust *t*-statistics are presented in parentheses. Significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

**Table 5.** Incremental costs associated with the CGBL (in yuan/m$^2$).

| Research | One star | Two star | Three star |
|---|---|---|---|
| Li and Sun (2008) | 36.6 | 281.7 | 302.7 |
| Sun and Shao (2010) | 63.0 | 131.0 | 219.0 |
| Zhang et al. (2011) | – | – | 427.0 |
| Qiu (2012) | 31.0 | 88.0 | 196.0 |
| Yip et al. (2013) | 16.0 | 35.2 | 68.0 |

website (introduced in section 'Data'). The variable is statistically significant at the 10% level, which implies that a self-advertised 'green' project can attract a price premium of 2.8%. However, this premium disappears when we introduce the *CGBL* dummy in column (2), while the coefficient of *CGBL* remains significantly positive. This implies that when a signal from the official green label is available, information from developers' self-advertisements has little effect. This pattern is further confirmed in column (3), when we divide the sample into four groups: CGBL-labelled and self-advertised projects (*CGBL_AD*), CGBL-labelled but not self-advertised projects (*CGBL_NOAD*), not CGBL-labelled but self-advertised projects (*NOCGBL_AD*), and the default group with projects that were neither CGBL-labelled nor self-advertised. The dummy variables for the CGBL-labelled projects, either self-advertised or not, are significantly positive in the model, although the green price premium is higher for the self-advertised group (8.1%) compared with the group without self-advertisement (6.9%). By contrast, the coefficient of the non-CGBL-labelled but self-advertised group is positive, but at most marginally significant.

## Conclusion

As a major step in promoting green building development, the Chinese central government introduced the CGBL as the official green label in 2008. In this paper, we focus on the existence and magnitude of the price premium associated with the CGBL in the residential sector, based on 163 labelled newly built housing projects around the country as well as their non-labelled counterparts. The empirical analysis in general provides very encouraging results. The CGBL certification has been well accepted by households as a reliable signal of residential buildings' performance in energy efficiency, and seems to be more effective than developers' self-advertisements. Accordingly, the transaction prices of units in a CGBL-labelled housing project can be expected to be 6.9% higher than their non-labelled counterparts, controlling for other factors. This green price premium is very likely to be sufficient to compensate for the incremental costs of adopting energy-efficient design and technologies. Such financial feasibility should encourage developers to continue their greening efforts.

For the policy makers, these results highlight that the importance of providing reliable information on buildings' performance in sustainability to overcome the information asymmetry problem, and thus facilitate the market mechanism in the green building sector. Such a role can be further enhanced via several aspects. For instance, the post-occupancy evaluation of the buildings with design certifications is a task with a top priority, as the facility management is crucial in the actual performance of green buildings. Furthermore, the financial viability revealed in this paper does not suggest that other incentives such as government subsidies are unnecessary. As emphasised by the World

Green Building Council (2013), since most information on the benefits and costs associated with energy-efficient investments is not publicly available, it is difficult for developers with no experience in green building development to reasonably assess the benefit-cost conditions. Therefore, government subsidies would be especially important to attract new green building developers.

While this research is a first step for the thorough understanding of the CGBL rating system from the economic aspect, there are several important issues on the agenda for future research. First, systematic research into the incremental costs of green buildings is conspicuously lacking, and a more elaborate benefit-cost analysis of different green attributes is important. Second, while this paper examines the price premium associated with the green label, analysis of how the actual performance of green buildings influences the resale prices and rents is called for. Third, more reliable evidence on the comparison of market recognition achieved by CGBL and LEED should be part of the future research. Finally, it would also be interesting and important to investigate whether (and to what extent) the green price premium or other economic or social factors affect the green building development in China.

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## Notes

1. By April 2013 there were 1156 LEED-registered and certified projects (including 56 residential projects) in mainland China, making China the country with the third-largest number of LEED-registered and certified projects in the world, after the US and Canada (http://www.usgbc.org/articles/infographic-leed-world).
2. Another potential problem is that the LEED rating is determined by the total points of all categories. A building can receive a high rating if it is outstanding in some areas, even if it performs poorly in other areas. Therefore, the LEED system may overlook some important but relatively difficult aspects of energy efficiency in China. See Zhu and Lin (2012) for more details.
3. See Ye et al. (2013) for more details on the application and evaluating procedures.
4. Some local governments also provide further incentives for developers' energy-efficiency investment, such as offering extra subsidies or additional floor area ratio.
5. We also use other distance thresholds, such as 1200 m and 800 m, and the empirical results are generally robust.
6. Most CGBL-labelled residential projects were certified at the design stage because the units were sold (typically pre-sold before completion) to households before they were able to apply for the operation certification.
7. Two of these 15 projects are also CGBL-labelled and one is within 1500 m of a CGBL-labelled project.
8. We adopt the dummy variable (*SUBWAY*) instead of the distance to subway stations, because only 11 of the 59 cities in our sample have subways and it is impossible to measure the distance to subway stations in the other 48 cities.
9. We identify the well-known developers according to the 'Top 100 Real Estate Developers in China' list released by a leading real estate market analysis institute in China (*ZhongZhi* Real Estate Institute) in March, 2014.
10. The number of groups is smaller than the number of CGBL-labelled projects since

some of the CGBL-labelled projects are close to each other (i.e. the distance between them is less than 1500 m), and thus are included in the same group.

11. We also test the use of the housing price as the dependent variable, and the results remain consistent.
12. In the following analysis, we only present results based on the basic specification to save space, but all the results are robust if we adopt any of the other three specifications. The results are available upon request.
13. One possible explanation here is, in most northern cities the charges for winter heating are calculated based on the housing area, instead of the amount of energy consumed.
14. The incremental costs of non-labelled housing projects are zero.
15. The price premium is calculated by multiplying the average housing price of non-labelled projects in this sample (9917 yuan/$m^2$) by the price premium ratio [$\exp(2.303 * 0.013) - 1 \approx 0.0304$].
16. Besides these construction costs, there are also consultation and application costs for the CGBL certification. According to current requirements, the total cost of consultation and application is at most one million yuan. Given that the average size of the CGBL-labelled residential project is about 133.7 thousand square metres of floor area, the average cost of application should be less than 8 yuan/$m^2$.
17. The price premium is calculated by multiplying the average housing price of non-labelled projects (10,250 yuan/$m^2$) by the price premium ratio (8.7%).

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